# EXPERIMENTAL SURFACE GILL NET FISHING FOR SKIPJACK IN HAWAIIAN WATERS

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Fish and Wildlife Service, Albert M. Day, Director

# EXPERIMENTAL SURFACE GILL NET FISHING FOR SKIPJACK (Katsuwonus pelamis) IN HAWAIIAN WATERS

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Walter M. Matsumoto
Fishery Research Biologist
Pacific Oceanic Fishery Investigations

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ILLUSTRATIONS

# EXPERIMENTAL SURFACE GILL NET FISHING FOR SKIPJACK (Katsuwonus pelamis) IN HAWAIIAN WATERS

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The tuna canning industry of Hawaii, utilizing the skipjack or striped tuna, Katsuwonus pelamis (Linnaeus 1758), is limited by its bait supply (Welsh 1949) and by the seasonal fluctuations in the catch. Recognizing the possibility that any drastic bait shortage could seriously curtail the skipjack fishery, local members of the Tuna Industry Advisory Committee for the Pacific Oceanic Fishery Investigations suggested a trial of gill nets as a possible means of taking these fish in commercial quantities without the use of bait. Accordingly, experimental fishing with gill nets was done intermittently during the period from July 2 to October 19, 1951, on the Territorial Division of Fish and Game's vessel Makua and the Fish and Wildlife Service's vessel John R. Manning. This experiment was a cooperative venture of the Fish and Wildlife Service and the Division of Fish and Game of the Territory of Hawaii.

The author wishes to thank the Division of Fish and Game, Territory of Hawaii for their cooperation and the use of the Makua, and Dr. William F. Royce, who offered valuable advice and encouragement in planning the experiment and in preparing the manuscript.

## HISTORY OF GILL NETTING FOR TUNA

Although the gill net is one of the oldest forms of nets employed in commercial fishing, the available literature on its application to fishing for tuna contains only meager information, and there is no report of its being used to any extent in this fishery until the early part of the twentieth century.

In northern Japan drift net fishing for black tuna, Thunnus orientalis (Temminck and Schlegel), began in 1905 at Kushiro, Urakawa, and Muroran, when this species was first captured in drift nets set for sharks. By 1927 the commercial fleet exceeded 200 vessels with a reported catch of over 8 million pounds. In the 1930's the fishery reached a flourishing condition at Kushiro and Urakawa (Kawana 1934), but in recent years it has died out almost completely with the failure of the black tuna runs and a shift to longlining.

In Peru, where the gill net is used successfully for bonito, Sarda chilensis, and skipjack, attempts at gill netting bonito were made by the U. S. Fishery Mission to Peru in 1941 with the vessel Pacific Queen (Fiedler, Jarvis, and Lobell 1941). Approximately 400 pounds of fish were caught during the 82 hours of the experiment, averaging 12 pounds per net and 4.9 pounds per hour. In general, the experiments indicated that it was uneconomical to fish with gill nets from a boat the size of the Pacific Queen.

More recently, nylon gill nets were used in an experiment in the Mediterranean Sea by a leading French nylon manufacturer (Anonymous 1950). Fishing was done at the dark of the moon, 5 to 6 fathoms below the surface. The tuna caught weighed from 26 to 110 pounds.

Off the west coast of North America, gill net experiments for albacore were conducted by the California Division of Fish and Game on the N. B. Scofield (Anonymous 1951). This experiment was made during the off season along the southern California coast to determine the whereabouts of the albacore rather than to test the method for possible commercial use, and consequently only a few albacore were caught.

Farther to the north the tuna explorations of the U. S. Fish and Wildlife Service vessel John N. Cobb, from June 12 to September 28, 1950, produced a catch of 169 albacore taken in one set (Powell 1950). Aside from this one sizable catch, the experiment in general did not show any immediate promise of success on a commercial scale. From July 6 to August 9, 1951, the gill net was again tried by the John N. Cobb. Albacore were caught in only 3 of the 13 sets made, with a total catch of 28 fish.

In Hawaii gill nets were used previous to 1883, but their use was limited to catching reef fishes and lobsters (Beckley 1886). Up to the time of the present experiment the only recorded attempt to use a drift net for tuna in this area was made by the California Division of Fish and Game vessel, N. B. Scofield, on its cruise to the Hawaiian Islands from July 21 to September 13, 1948 (Godsil and Greenhood 1949). Gill net fishing was carried out on an experimental scale but only a few fish were caught.

## DESCRIPTION OF GEAR

The drift gill net is designed to catch pelagic fishes swimming close to the surface of the water. The depth at which the nets are to fish can be regulated by adjusting the float lines. In effect, the net is an upright wall of netting made of a suitable material with an appropriate mesh to permit fish of a certain size to pass only part way through. Usually the fish is caught when

the mesh catches beneath its gill covers and prevents its swimming either forward or backward. Often when the fish strikes the net it may penetrate the mesh until it gets caught at the thicker part of the body, provided the girth is larger than the size of the mesh. The fish may also be caught by becoming entangled in the meshes without being gilled.

The gill net (fig. 1) used in the present fishing experiment[1/] for skipjack in Hawaiian waters was constructed on the pattern of the albacore net used on the John N. Cobb during its 1950 tests. Eight to 14 "shackles" of net, each measuring 50 fathoms in length and 100 meshes deep, were connected in a "string" at each setting. A 16-inch air-inflated rubber float was attached to the float line between shackles and at each end of the string. A "sea anchor," made by lashing together three or four rope fenders around a lead weight, was attached to the lead line at the free end of the first shackle, while a 60- to 70-fathom bridle was attached to the float and lead lines of the last shackle. The lead line was kept from rolling up on the net by a 25-pound lead ball which was attached at the junction of the bridle and lead line. During night fishing buoy lights were attached to the 16-inch rubber floats at the center and both ends of the net.

A total of 16 shackles, eight of 8-ply salmon-lay nylon and eight of 40/8-ply linen, were constructed in stretched-mesh sizes of 4, 5, 6, 7, 9, 10, 11, and 12 inches.

The individual shackle (fig. 2) was made up of the following parts:

(1) Netting. The netting was made of double-knotted nylon and linen which measured 100 fathoms in length and 100 meshes deep with double selvage. The depth in fathoms ranged from 3-1/3 for the 4-inch mesh to 16⅔ for the 12-inch mesh. The 100-fathom netting was hung on a 50-fathom float line (2:1 hanging ratio), and was attached at every second mesh with 40/11-ply linen twine.

(2) Float line. The float line consisted of 50 fathoms of 24-thread soft-laid Manila, 17/32 inch in diameter, with an additional 20 inches at each end.

(3) Floats. The 6-inch diameter round glass floats were tightly wrapped in 1½-inch mesh webbing of No. 27 medium-laid cotton thread. These floats were attached to the float line with 261-thread hard-laid cotton straps 13 inches long at 2-fathom

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1/ The modification and construction of the nets were supervised by Kalfred Yee, formerly Fishery Methods and Equipment Specialist, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service.

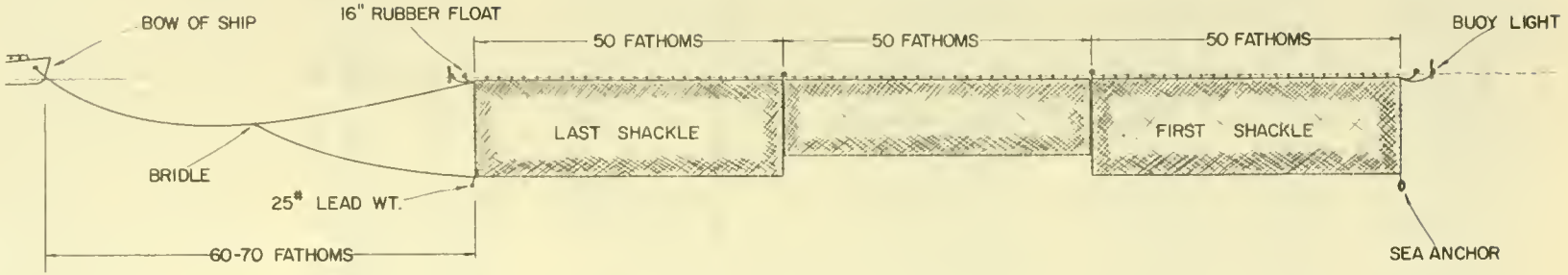


FIG. I. PLAN OF GEAR IN OPERATION

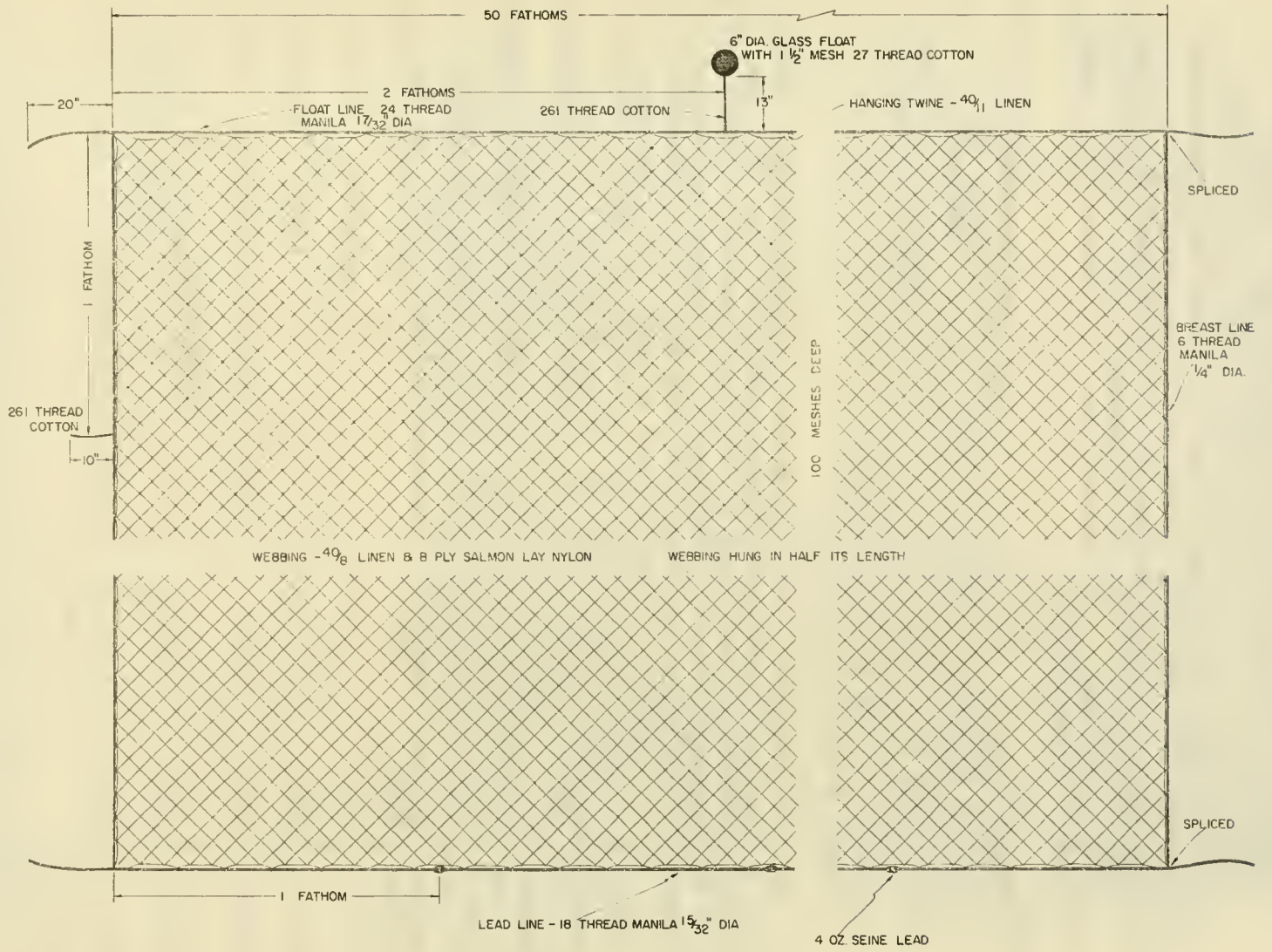


FIG. 2. DETAILS OF INDIVIDUAL SHACKLE

intervals. At first glass floats were used on all the shackles. However, upon discovering that these floats too easily became entangled in the larger meshes, they were replaced by 8 x 10-inch metal floats on the nets of 10 and 11-inch mesh, and the use of the 12-inch mesh was discontinued.

(4) Lead line. The lead line consisted of 50 fathoms of 18-thread soft-laid Manila, 15/32 inch in diameter, with a 20-inch extension at both ends. This was weighted with 4-ounce seine leads spaced 1 fathom apart.

(5) Breast line. A breast line of 6-thread soft-laid Manila, $\frac{1}{4}$ inch in diameter and equal in length to the depth of the netting, was used at each end of the shackle. The ends of this line were spliced on to the float and lead lines. Straps of 261-thread hard-laid cotton line 10 inches in length were used to tie the shackles together and these were placed 1 fathom apart on the breast line.

All the linen nets were treated with net preservatives: the 4, 6, 9, and 11-inch mesh sizes with Dura Nett 200, an acid-free plastic preservative, and the 5, 7, 10, and 12-inch mesh sizes with the New Lodge Process, a combination of a plastic and copper napthenate. The nylon nets were first used without any preservative. After these nets failed to catch a single fish, they were treated with preservatives, more for their staining than for their preserving effect, as the latter was unnecessary with the nylon. The 4, 7, and 11-inch mesh sizes were treated with the New Lodge Process, the 5, 6, and 10-inch mesh sizes with Net Life (green), a preservative with a soluble copper base, and the 9 and 12-inch mesh sizes with Dura Nett 200. The preservatives increased the weight of the nets by 28 to 50 percent. The detailed account of the cost and the time consumed in completing the nets is shown in the following tables.

Table 1.--Itemized cost of supplies and materials[1/] for the construction of 16 shackles of gill net.

| Item | Quantity | Cost/unit | Cost |
|---|---|---|---|
| Linen netting | 8 pieces | $275.00 | $2,200.00 |
| Nylon netting | 8 pieces | 560.63 | 4,485.04 |
| Cotton netting | 52 lbs. | 2.35 | 122.20 |
| 6-inch glass float | 450 | 0.32 | 144.00 |
| 8 x 10-inch metal float | 32 | 3.85 | 123.20 |
| 16-inch rubber float | 16 | 6.45 | 103.20 |
| 4-ounce lead seine sinker | 200 lbs. | 0.23 | 46.00 |
| Buoy light | 4 | 15.00 | 60.00 |
| Buoy light bulb | 18 | 0.11 | 1.98 |
| Buoy light battery | 8 | 2.50 | 20.00 |
| 6-thread soft-laid Manila rope | 3 coils | 12.60 | 37.80 |
| 18-thread soft-laid Manila rope | 4 coils | 34.84 | 139.36 |
| 24-thread soft-laid Manila rope | 4 coils | 34.84 | 139.36 |
| 40/8-ply linen twine | 9 lbs. | 4.25 | 38.25 |
| 40/11-ply linen twine | 6 lbs. | 4.25 | 25.50 |
| 8-ply nylon twine | 20 lbs. | 7.85 | 157.00 |
| Dura Nett preservative (50-gal. drums) | 2 drums | 117.00 | 234.00 |
| New Lodge Process preservative (50-gal. drums) | 2¼ drums | 37.00 | 83.25 |
| Net Life preservative (50-gal. drums) | 1-1/3 drums | 72.00 | 96.66 |
| Total | | | $8,257.60 |

1/ All prices are as delivered at Honolulu, T. H. Costs of the net roller, hard-rubber V-roller, and construction of the net box are not included.

Table 2(a).--Itemized construction time per shackle

| Description of work | Man-days per shackle | |
|---|---|---|
| | With glass floats | With metal floats |
| Attaching float line | 5 | 5 |
| Attaching lead line | 5 | 5 |
| Attaching breast line | 1 | 1 |
| Attaching floats | 1½ | ½ |
| Treating with preservatives | ½ | ½ |
| Total | 13 | 12 |

(b).--Time required to complete entire net

| Item | No. | Man-days/shackle | Total man-days |
|---|---|---|---|
| Shackles with glass floats | 13 | 13 | 169 |
| Shackles with metal floats | 4 | 12 | 48 |
| Total man-days for 17 shackles[1/] | | | 217 |

(c).--Total cost of net

| Item | Cost |
|---|---|
| Supplies and materials | $8,257.60 |
| Labor for 217 man-days at $9.00/man-day[2/] | 1,953.00 |
| Total | $10,210.60 |

1/ Subtotals adding up to more than 16 shackles are due to replacing 6-inch glass floats with 8 x 10-inch metal floats on 2 shackles and eliminating work on one 12-inch shackle.

2/ The $9.00/man-day is an approximate figure.

## FISHING OPERATIONS

The fishing operations on the Makua[2/] and on the John R. Manning differed only in the amount of gear used and the method by which the nets were retrieved. In all other respects the operations were nearly identical. The Makua, having an overall length of only 45 feet, offered very little deck space for piling the net preparatory to setting it. The number of shackles in any single set was thus limited to eight. The net was set from the stern of the vessel and the floats were kept toward the wind whenever possible to minimize the chances of tangling. Sets were made under sea conditions ranging from calm to moderately rough (height of waves approximately 2-5 feet) with a maximum wind velocity of 25 miles per hour. The net was fished both during the day and at night, and whenever the weather and sea conditions permitted it was drifted free of the vessel. When sea conditions were unfavorable, the string of nets was secured to the bow of the vessel by the bridle line to facilitate the retrieve at night, if any emergency arose.

The net was hauled in manually by two or three men at the bow as the vessel moved ahead parallel to it, and it was then passed along the deck to the stern, where it was repiled for the next set. Retrieving time for the eight shackles of gear averaged a little over 2 hours when there was no catch. The time consumed in removing the catch from the net prolonged this operation, especially with the larger fish such as sharks and rays, which became entangled in the webbing.

Fishing on the Makua was limited to the Kona coast of the island of Hawaii between Kolo and Kailua (fig. 3). A total of 11 sets, 4 daylight and 7 night, were made at distances ranging from 1-3/4 to 15 miles from the shoreline. All the night sets were made at 1 to 2 hours before sunset and were picked up the following morning. The actual fishing time for all the sets totaled 125 hours, 76 at night and 49 during daylight, with an average of 11.3 hours of fishing per set.

The John R. Manning, an 86½-foot purse seine vessel, afforded ample working space. The net was arranged and piled in the net box, which was of sufficient size to contain the entire gear. Each shackle was tied to the succeeding one by the float line and by the connecting straps which were placed along the breast lines. The floats were arranged at one side of the box in such fashion as to permit the setting operation to be carried out without tangling. In setting, the buoy light and sea anchor, which were attached to the free end of the net, were let out first and the rest of the net was drawn out as the vessel moved ahead. The vessel drifted with the net secured to the bow during the entire time the net fished.

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2/ Gear tests and fishing operations on the Makua, May 22-24, and July 2-26, were conducted by Kalfred Yee, formerly Fishery Methods and Equipment Specialist, U. S. Fish and Wildlife Service.


FIG 3 LEE AREAS IN THE HAWAIIAN ISLANDS

On the retrieve, the net was hauled in from the starboard side of the vessel. It was passed over the net roller, across a table, and through a V-shaped roller on the winch. From the V-shaped roller it was passed into the net box, where it was repiled in preparation for the next setting. The entire procedure, from the time the net was hauled out of the water until it came to rest in the net box, was done in one continuous operation, stopping only to remove fish from the net; this was done on the table. The time required to haul in 10 to 14 shackles averaged 1½ hours.

The John R. Manning fished only off the leeward coasts of Oahu, Kauai, and Hawaii since they presented the largest lee areas (fig. 3). Off Oahu fishing operations were attempted between Maile and Kaena Point from 3 to 15 miles offshore. Off Kauai fishing was carried out in the area between Port Allen and Mana Point from 2 to 5½ miles offshore. At Hawaii, although the leeward area was very extensive, fishing was done only off Kealakekua Bay from 5 to 7 miles offshore (table 3). Depth of waters at the time the net was set ranged from 200 to 1,570 fathoms; however, the net frequently drifted inshore to depths of 28-30 fathoms.

Table 3.--Dates and areas fished by both vessels

| Vessel | Date fished | Hours fished | Area | Total catch (all species) |
|---|---|---|---|---|
| Makua | July 5-19 | 125 | Hawaii | 15 |
| Manning | Sept. 26-29 | 54¼ | Oahu | 4 |
| | Oct. 16-18 | 38½ | Oahu | 4 |
| | Oct. 3-5 | 39-3/4 | Kauai | 2 |
| | Oct. 11-12 | 26½ | Hawaii | 2 |

The net fished a total of 159 hours from the Manning with only 1½ hours of this fishing time during daylight. This daylight set was made on a trial basis to observe the setting and retrieving operations, and to plan the retrieving procedure as efficiently as possible.

The catches of the two vessels are listed in table 4. It should be noted that most of the tuna were taken in the smaller meshes (6 inches and less) and that these comprised approximately

Table 4.--Details of gill net catches

| Date | Time | Location | Species | Size | Net and Mesh size |
|---|---|---|---|---|---|
| MAKUA | | | | | |
| 7/5/51 | Night | 4 mi. off Kealakekua Bay, Hawaii | Skipjack *Katsuwonus pelamis* | 18.0 in. | 5" linen |
| 7/6 | Night | 3 mi. offshore between Hookena and Napoopoo, Hawaii | Dolphin *Coryphaena hippurus* (not gilled) | 3 lbs. | 4" nylon |
| 7/6 | Night | " | Skipjack *Katsuwonus pelamis* | 21.7 in. | 7" linen |
| 7/9 | Night | 6 mi. off Kolo, Hawaii | Sand shark *Eulamia sp.* | about 125 lbs. | 11" linen |
| 7/9 | Night | " | Skipjack *Katsuwonus pelamis* | 18.4 in. | 5" linen |
| 7/10 | Night | 1 mi. off Puu Ohau Hawaii | Frigate mackerel *Auxis thazard* | 3 fish 14.1-14.4 in. | 11" linen |
| 7/12 | Day | 4 mi. off Keauhou, Hawaii | Manta ray *Manta birostris* | about 300 lbs. | 11" nylon |
| 7/16 | Night | 4½ mi. off Kealakekua Bay, Hawaii | Skipjack *Katsuwonus pelamis* | 25.9 in. | 6" linen |
| 7/18 | Day | 6 mi. off Auau Point, Hawaii | Dolphin *Coryphaena hippurus* | about 3 lbs. | 5" nylon |
| 7/19 | Day | 15 mi. off Hoonaunau, Hawaii | Trigger fish *Balistes sp.* | about 1 lb. | 7" nylon |
| 7/19 | Day | " | " | " | 5" linen |

Table 4.--Details of gill net catches (Continuted)

| Date | Time | Location | Species | Size | Net and Mesh size |
|---|---|---|---|---|---|
| MANNING | | | | | |
| 9/26/51 | Night | 4 mi. SW of Waianae, Oahu | Black marlin *Makaira mazara* | 158 lbs. | 5" linen |
| 9/27 | " | 12-3/4 mi. WSW Puuhulu Ridge, Oahu | White-tipped shark *Triaenodon obesus* | 130 lbs. | 11" nylon |
| 9/27 | " | " | " | " | 9" nylon |
| 9/28 | " | 15½ mi. SW Waianae, Oahu | Filefish *Monocanthidae* | --- | --- |
| 9/29 | " | 4½ mi. SW Waianae, Oahu | Dolphin *Coryphaena hippurus* (not gilled) | 50.1 in. | 5" nylon |
| 10/4 | " | 3 mi. off Mana Point, Kauai | Skipjack *Katsuwonus pelamis* | 18.2 in. | 5" nylon |
| 10/5 | " | 2 mi. SW of Kokole Point, Kauai | Little tunny *Euthynnus yaito* | 22.0 in. | 10" linen |
| 10/12 | " | 5½ mi. W off Kealakekua Bay, Hawaii | Barracuda *Sphyraena barracuda* | 35.7 in. | 4" linen |
| 10/12 | " | " | Manta ray *Manta birostris* | about 500 lbs. | 11" nylon |
| 10/16 | " | 13½ mi. SW of Pokai Bay, Oahu | White-tipped shark *Triaenodon obesus* | about 90 lbs. | 10" linen |
| 10/16 | " | " | " | about 70 lbs. | 10" nylon |
| 10/16 | " | " | " | about 50 lbs. | 11" nylon |
| 10/17 | " | 4-3/4 mi. WSW of Pokai Bay, Oahu | Manta ray *Manta birostris* | about 400 lbs. | 10" nylon |

half the total amount of net. The total hours spent in fishing by both vessels was 294, with a total of 196 shackles set. The catch per unit of effort was 0.13 fish including 0.04 tunas per shackle, but if allowance is made for half of the mesh being too large, the catch per shackle is double that indicated.

Several factors affected the fishing operations, the most noticeable of which were wind, current and sea conditions. Although the upper limits of these factors were not investigated thoroughly, it was possible to fish with the wind velocity up to 30 knots. Winds of this force caused heavy strain on the gear and especially on the line by which the net was secured to the vessel. The strain was somewhat reduced by the addition of more line.

Strong currents were a constant source of concern. Although the net was usually set across or obliquely to the direction of the current, it often swung around to a position parallel to the current during the set. In localities where the current changed its direction of flow several times during the night, the net folded upon itself, thus presenting only a part of its length to actual fishing. Drifting over 15 miles during the night was not uncommon, and in several instances where the current was extremely rapid, the net drifted into the wind even though the wind velocity exceeded 28 knots. The current also affected the vertical angle of the net. During one of the cross-current sets, a current of approximately 1/2 knot caused the net to fish at a 35-40 degree angle with the surface. This was probably due to the shear between the surface and the lower water layer, or to the effect of the wind acting on the floats in a direction opposite to the current, or possibly to a combination of both. However, the velocity of the wind was only about 10 knots on this particular set.

Sea conditions affected the retrieving operation greatly. The ship's roll, due to large swells, caused great strain on the net, and often this resulted in numerous tears in the webbing along the lead and float lines. The Manning worked in swells up to 7 feet in height. A smaller vessel probably could have performed this operation in much rougher water with less damage to the gear. It was evident from the first few sets that the net could only fish safely from the Manning in areas of calm water.

## FISHING GROUNDS AND SEASONS

The observations made on the fishing areas showed that in the Hawaiian Islands calm waters are found only in the leeward areas of the islands of Hawaii, Oahu and Kauai. Only at two islands, Hawaii and Oahu, does this lee extend much beyond 15 miles from shore. At Kauai it extends only 4 or 5 miles. The lee at Maui, although it is

relatively calm, is broken up into several large channels swept by strong currents; consequently it is not feasible to use the gill net in this area. Drift net fishing can usually be done with safety to the gear in the calmer waters bordering Hawaii, Oahu, and Kauai during the entire year and during the summer off the islands of Lanai and Molokai.

Along these leeward areas the wind shifts from NE to SW at night and back to NE as morning approaches. The general pattern at all the islands is nearly identical, but the extent of this shift varies greatly between islands depending on the size and formation of the mountains. The velocity, too, often varies from 0 to 30 knots during the night. The wind by itself does not seriously hamper the operations, but when it occurs simultaneously with strong currents and adverse sea conditions, fishing becomes very difficult. The currents themselves are also variable both with respect to time and intensity at the various localities and even within the same locality. Of two sets made on September 26 and 27 in approximately the same locality, the first set drifted more than 15 miles while the latter drifted only about 7 miles and somewhat obliquely to the drift of the first set.

Consequently, the allowance for the drift, the prevailing leeward wind velocity and direction, and the anticipated morning sea conditions tend to circumscribe the area of operation. The numerous small craft and barges plying between the islands and the activities of commercial and sport fishing vessels at times make the operations hazardous. However, this situation could be overcome by fishing the net deeper, if the gill net should be used commercially.

The fishing seasons, as determined from the skipjack landings by the live bait fishery, show considerable changes during the year and from season to season (fig. 4). The first sizable catches of skipjack by the commercial fishery are usually made in May. After increasing to a maximum in June or July, the catches drop off gradually until October or November, small catches, however, are made in most years throughout the year.

The John R. Manning fished extensively off the leeward coast of Oahu in the Waianae-Kaena Point area, the most productive skipjack ground in the Hawaiian Islands, during a period when fish should have been fairly abundant (tables 3 and 5). The occurrence of skipjack schools was recorded regularly on this cruise as follows. During a period of 17 days with an average of 5 hours per day spent in scouting for tuna, a total of 12 fish schools were sighted under bird flocks and one school without any accompanying birds. Nine flocks of birds were also sighted, and although no fish were seen, the types and behavior of the birds indicated the presence of skipjack. Half of the schools were sighted in open water where it was impossible to

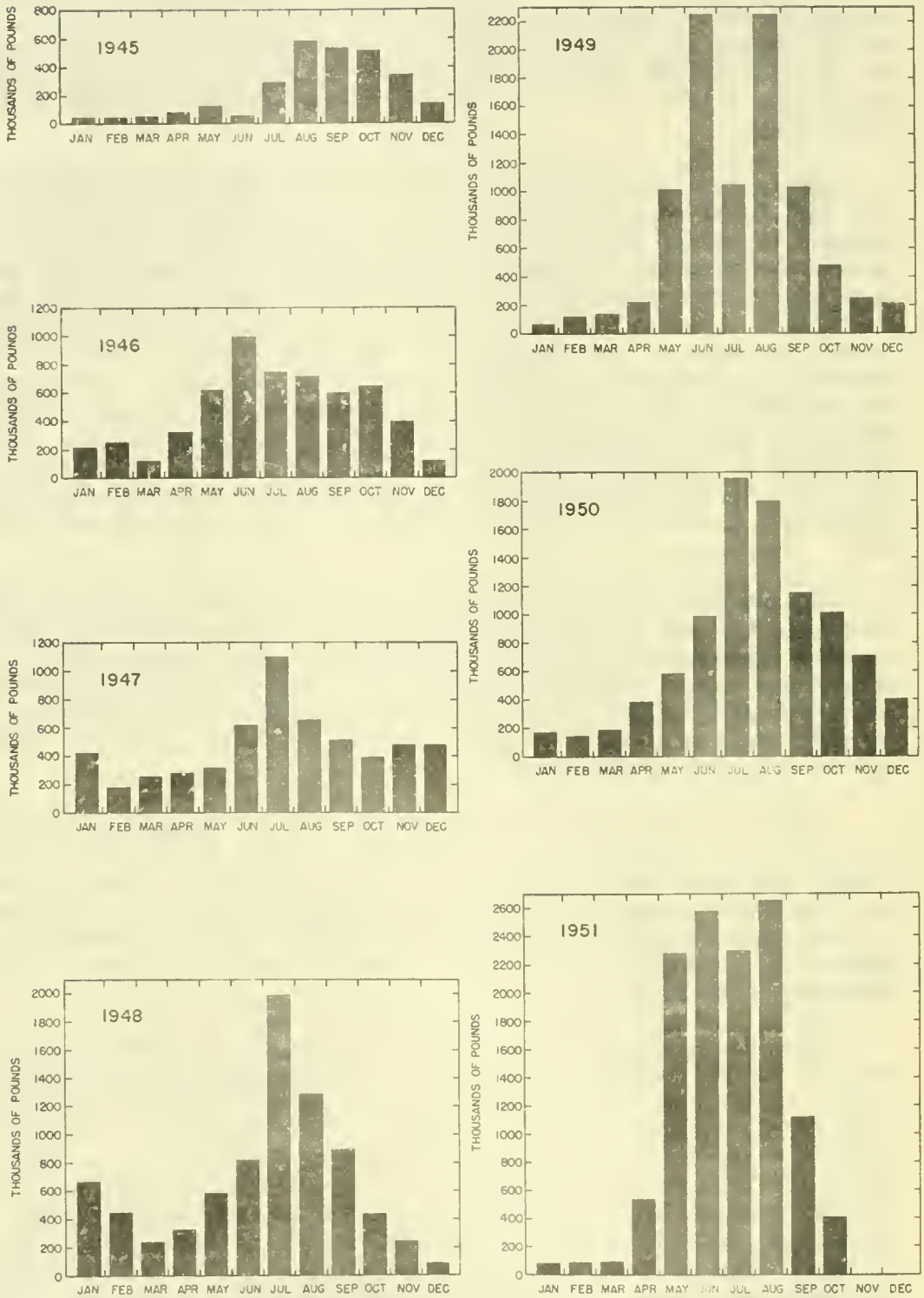


FIG 4 HAWAIIAN SKIPJACK LANDINGS BY MONTHS, 1945-1951

Table 5.--Skipjack landings in pounds from the three leeward areas, 1948-1950

| Month | Kauai | | | Kona, Hawaii | | | Waianae-Kaena Pt., Oahu | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1948 | 1949 | 1950 | 1948 | 1949 | 1950 | 1948 | 1949 | 1950 |
| Jan. | -- | 1,710 | 200 | -- | -- | 9,200 | 68,642 | 175 | 19,160 |
| Feb. | -- | 11,583 | 5,393 | -- | -- | 8,125 | 44,010 | 13,383 | 53,147 |
| Mar. | -- | 7,550 | 3,628 | -- | -- | 7,078 | 12,692 | 122 | 39,045 |
| Apr. | -- | 4,408 | 12 | -- | -- | 29,382 | 47,759 | 9,153 | 137,691 |
| May | 4,628 | -- | -- | -- | -- | 11,840 | 36,608 | 29,732 | 173,074 |
| June | 10,780 | 8 | -- | -- | -- | 136 | 91,239 | 123,330 | 263,273 |
| July | -- | 8 | -- | 418 | -- | -- | 202,112 | 130,612 | 175,405 |
| Aug. | -- | 42 | -- | 70 | 21 | -- | 201,173 | 325,415 | 295,282 |
| Sept. | 20,950 | 7,560 | 3,635 | -- | -- | -- | 64,891 | 55,050 | 140,551 |
| Oct. | 29,386 | 10,553 | 21,391 | -- | -- | 37,225 | 23,023 | 13,878 | 90,457 |
| Nov. | 65,985 | -- | 30,406 | -- | 18,608 | 4,575 | 5,867 | 5,331 | 135,817 |
| Dec. | 23,825 | 21,692 | 62,246 | -- | 14,855 | 5,825 | 2,674 | 15,569 | 31,660 |
| Totals | 155,554 | 65,114 | 126,911 | 488 | 33,484 | 113,335 | 800,690 | 721,747 | 1,554,562 |

Note: Data from the catch records of the Territorial Division of Fish and Game.

make a set without risking considerable damage to the net. However, skipjack were present in the fishable area in fair quantities. Nevertheless, the catch by the John R. Manning was less than that made by the Makua, although the Makua fished off the Kona coast exclusively and made very poor catches (table 3).

## DISCUSSION

Before attempting to draw any conclusions from the experiments conducted, certain factors must be considered. A more definite knowledge of the migratory habits of the fish is necessary. Although it is a common belief among the commercial fishermen that the skipjack tend to migrate offshore as evening approaches and return to the shoal areas in the morning, no one has attempted to investigate what paths the skipjack follow in this nocturnal migration. The fishermen's observations are made only on the surface schools which they happen to encounter at sunset during fishing operations. There is a possibility that the majority of the skipjack sound and disperse or migrate offshore through the deeper waters at nightfall and return to the shoals along the same paths at daybreak. Whether the skipjack school at night is also not definitely known, but the few skipjack caught during the experiment suggest that they do not. All of them were taken singly or in pairs at rather wide intervals and close to the surface.

There also is a possibility that the skipjack can see the net and avoid it. Several observations made on the visibility of the net in the water during daylight and at twilight showed that the untreated nylon shackles and those treated with Dura Nett 200 were clearly visibile down to the lead line. Those treated with Net Life (green) and the New Lodge Process (black) were less visible, the latter being the least noticeable. It is not certain whether the skipjack see the net and avoid it, but a few incidents which occurred during the experiment seem to suggest that they do. On two of the sets scattered flocks of birds were seen milling around and passing over the net, but the only catch was one skipjack on one of the sets. If these bird flocks were associated with schools of skipjack, the poor catch possibly could have been due to the skipjack's ability to see the net. Night observations showed phosphorescence along the net, but it was not possible to determine whether this affected the fishing.

While a sufficient number of schools were observed near Oahu and Kauai to suggest the presence of fairly large numbers of skipjack, the observations were made during the day, and there is some basis for believing that these fish were not available for capture at night.

## SUMMARY AND CONCLUSIONS

1. A surface gill net designed to take skipjack was fished experimentally in Hawaiian waters a total of 284 hours, of which 233½ hours were fished at night.

2. Fishing was done only in the lee of the larger islands because of difficulty in handling the gear in rough water. However, part of the experiment was performed in an area known to be a productive skipjack ground and during the known season of abundance of this species.

3. The total catch of 28 fish of which only six were skipjack, showed a very poor catch per unit of effort.

4. It is concluded from the results of this experiment that surface gill netting shows little promise as a commercial fishing method for skipjack in Hawaiian waters.

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